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Matching AIRS and MODIS radiances in cloudy scenes

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Objectives / Agenda

- Problem
  - AIRS spatial response not equal for all channels
  - Results in discontinuities in measured spectrum at array boundaries in Nonuniform Scenes
  - Only a affects roughly 1% of scenes (with most cloud variability)
- Current Solution
  - Level 1C. Uses PC reconstruction for most affected channels; leaves all other channels unchanged (passed through as L1B)
  - Reconstruction can leave residual biases when “semi-bad” channels are included or too few channels left to build the reconstruction
- Alternate Method
  - Use MODIS data to flat-field AIRS response. Requires matching AIRS and MODIS radiances in nonuniform scenes using AIRS Point Spread Functions (PSFs)
- Value and Future Applications
  - Compare flat field response to AIRS Level 1C
  - Use flat-field correction prior to Level 1C
  - Data fusion for improved spatial resolution atmospheric sounding products

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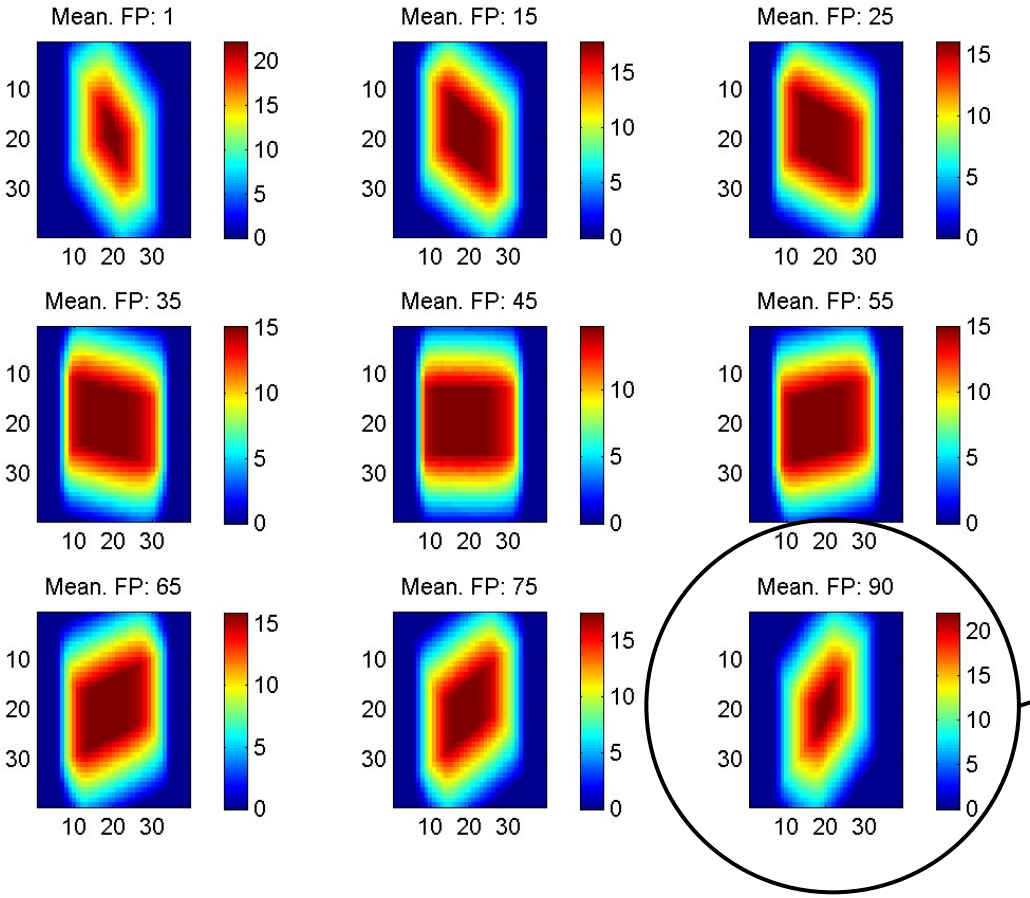
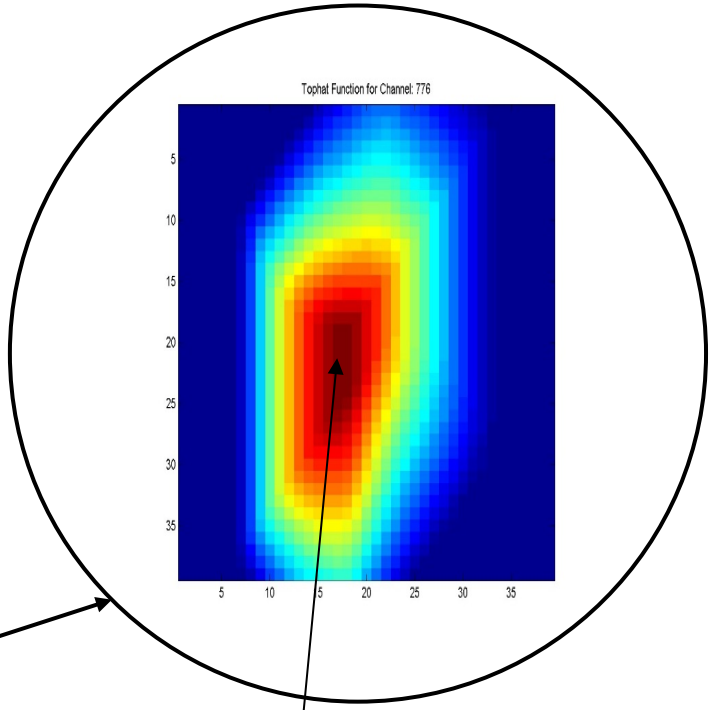
Individual Point Spread Function (PSF), R_j, Can Differ from Average Spatial Response, R_o

AIRS Average Spatial Response Functions
39 x 39 Pixels, 90 Footprints



Individual Spatial Response Function for Channel 776 Footprint 90



Centroid is defined as the position weighted integral of the AIRS Spatial Response Function in two dimensions

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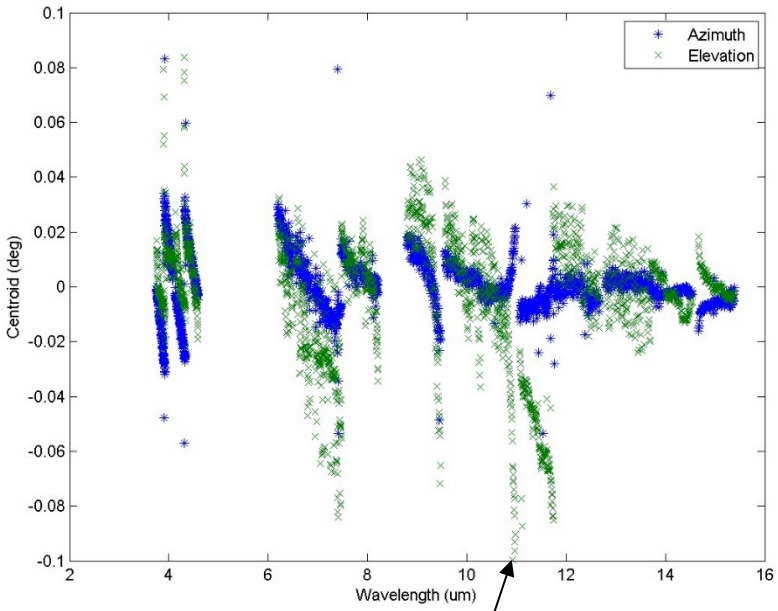
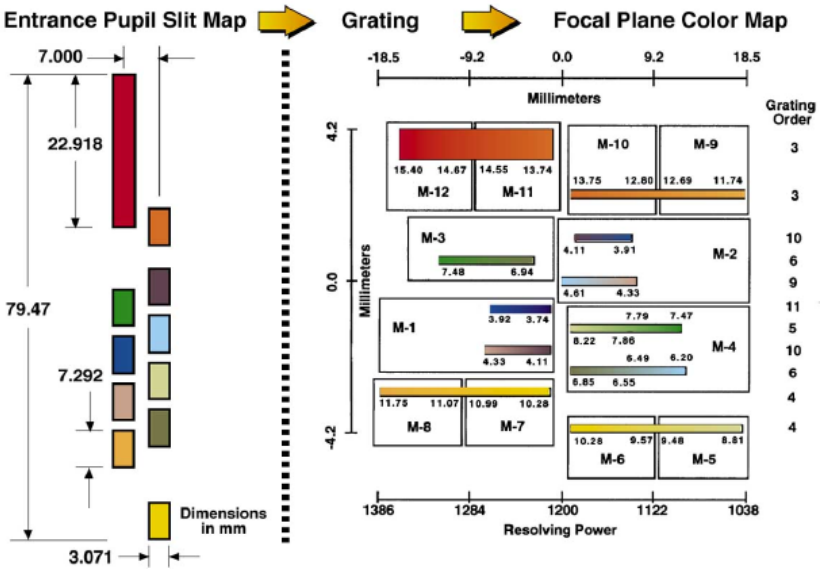
AIRS Centroids Depend on Detector Module

Centroid of AIRS IFOV
IFOV = 1.1°



Centroids can be off by as much as 0.1° (10% of a pixel)

AIRS Slit and Detector Map



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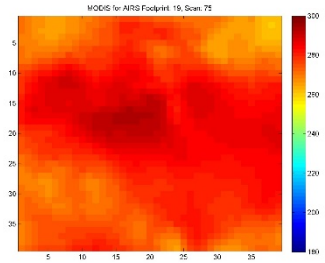
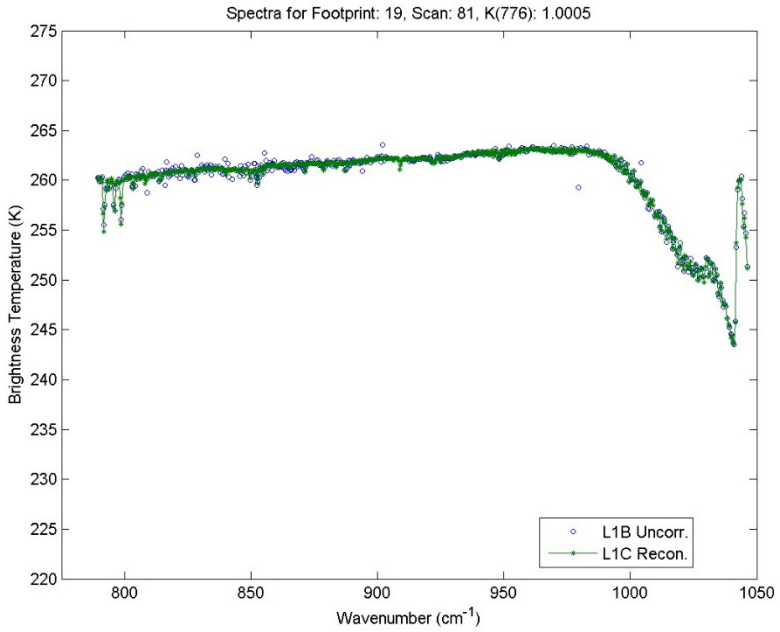
Centroid Error Leads to Noisy Spectra in High Contrast Scenes

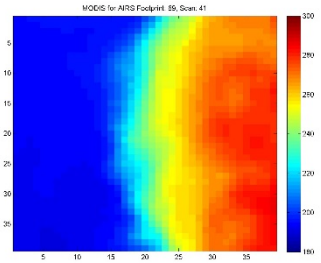
Low Contrast AIRS Pixel
FP 19, Scan 81



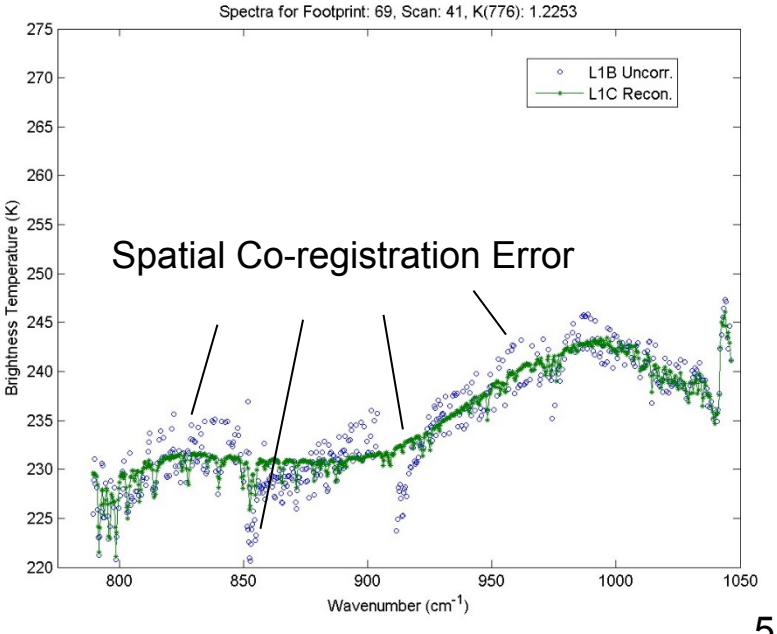
MODIS Image Within the AIRS Pixel



High Contrast AIRS Pixel
FP 69, Scan 41



MODIS Image Within the AIRS Pixel



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Irregular AIRS Spatial Response Profiles can be Normalized to "Flat-Field" AIRS Spatial Response

- The spatially averaged radiance from AIRS depends on the scene and AIRS spatial response:

$$L\downarrow AIRS,i = \sum x\uparrow \sum y\uparrow L\downarrow i\,(x,y)\; R\downarrow i\,(x,y) \;/ \sum x\uparrow \sum y\uparrow R\downarrow i\,(x,y) \qquad (1)$$

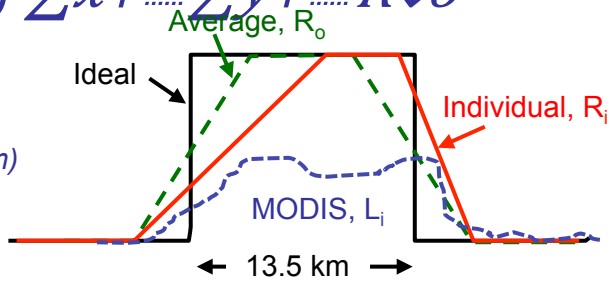
Where

- $L_{AIRS,I}$ = *AIRS L1B Radiance in the i^{th} Channel (w/m^2-sr-μm)*
- L_i = *Scene radiance in the i^{th} channel (W/m^2-sr-μm)*
- R_i = *AIRS Spatial Response Function (unitless)*
- *x,y = Longitude and Latitude of the AIRS PSF Grid (deg)*

- If we know the scene radiance, we can correct for an irregular spatial profile by normalizing it to the signal that would result using an "average" spatial profile (i.e. Flat-Field AIRS Response)

$$L'\downarrow AIRS,i = \sum x\uparrow \sum y\uparrow L\downarrow i\,(x,y) R\downarrow o\,(x,y) \sum x\uparrow \sum y\uparrow R\downarrow i\,(x,y) \;/ \sum x\uparrow \sum y\uparrow L\downarrow i\,(x,y)\; R\downarrow i\,(x,y) \sum x\uparrow \sum y\uparrow R\downarrow o\,(x,y)\; L\downarrow AIRS,i \qquad (2)$$

- Where
- $L'_{AIRS,i}$ = *Spatially Corrected AIRS Radiance in the i^{th} channel (w/m^2-sr- μm)*
- L_i = *Scene radiance in the i^{th} channel (w/m^2-sr-μm)* **MODIS**
- R_o = *Average AIRS Spatial Response Function (of all channels)*



- The MODIS averaged radiance (to compare with $L'_{AIRS,i}$) must also be weighted by the average AIRS spatial profile.

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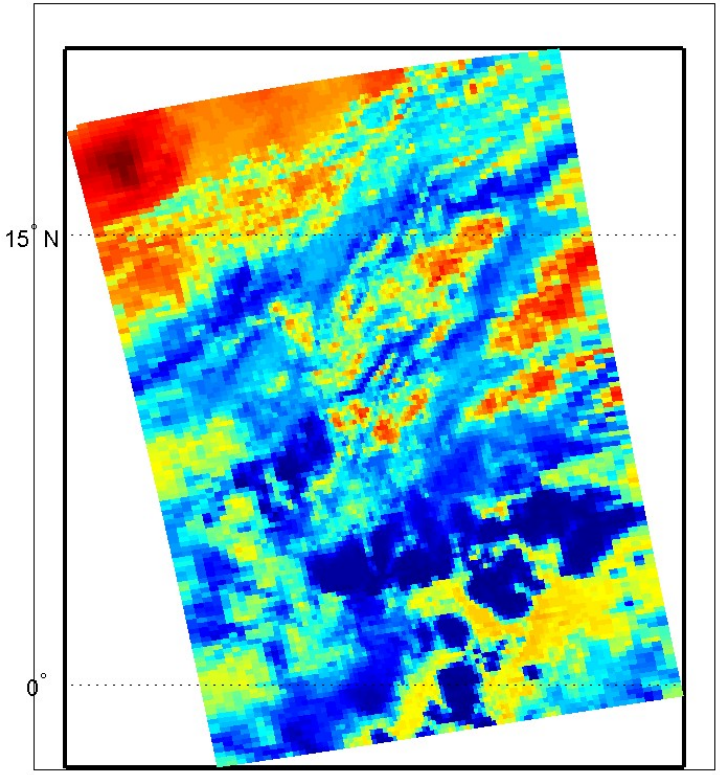
Test Granule: 2014.03.01.124 AIRS and MODIS Data

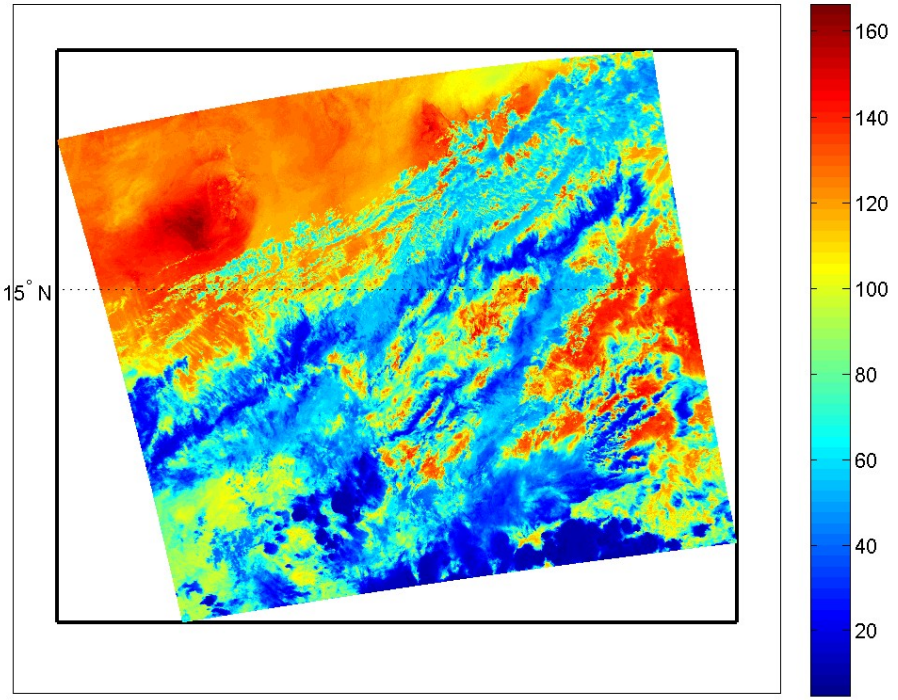
AIRS Window Channel: 11.1μm

AIRS.2014.03.01.124.L1B.AIRS_Rad.v5.0.22.0.G14061104808.hdf.mat



MODIS Window Channel: 10.8 μm

MYD021KM.A2014060.1225.006.2014061170219.hdf.IR.mat



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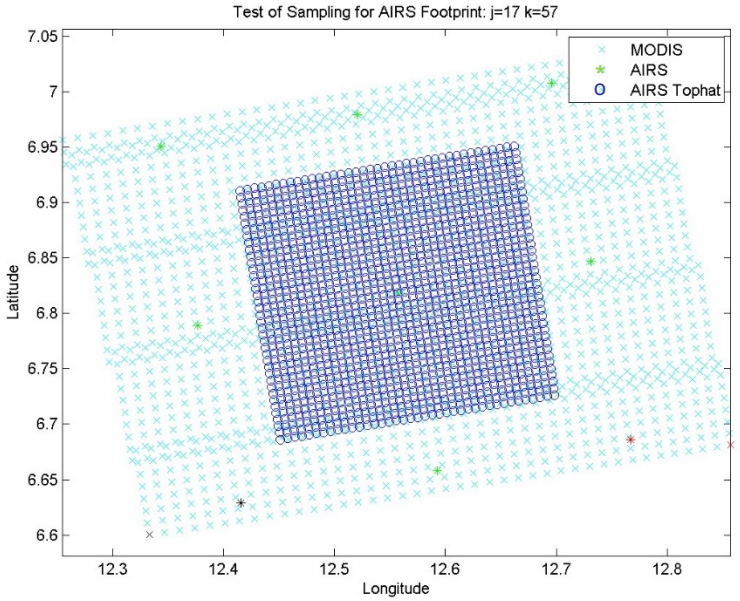
Correction Process

1. Load AIRS and MODIS Data for Same Location and Time
2. Load AIRS Individual and Average PSF (39x39pixels)
3. For Each AIRS Footprint
4. Find closest 40x40 MODIS pixels around Lat, Lon of AIRS footprint
5. Project AIRS PSF to Lat, Lon
6. Resample MODIS to AIRS PSF Grid
7. Use resampled MODIS data as "scene radiance", L_i in Equation 2 with individual and average PSF to get corrected AIRS radiance.
8. Use resampled MODIS weighted by AIRS average PSF (Equation 3) as a comparison data set.

MODIS Lat/Lon Overlaid with AIRS PSF Grid



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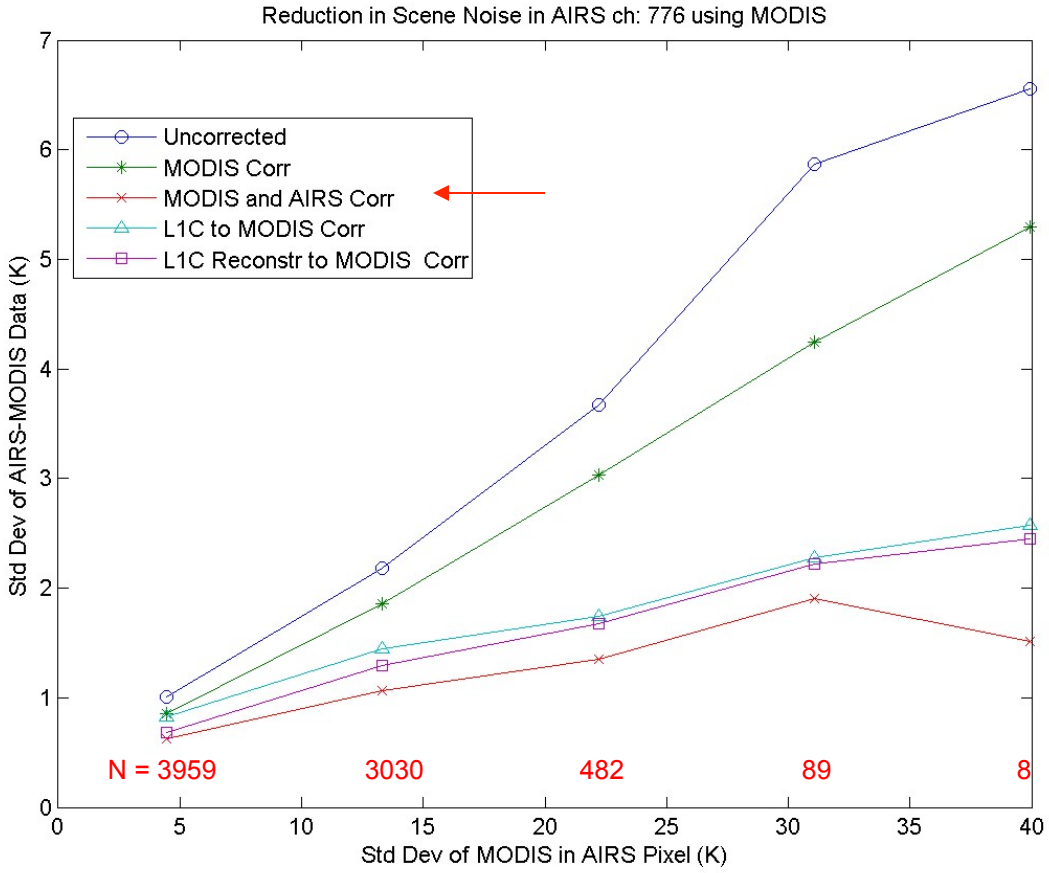
Flat-Fielding Reduces Noise in Non-Uniform Scenes



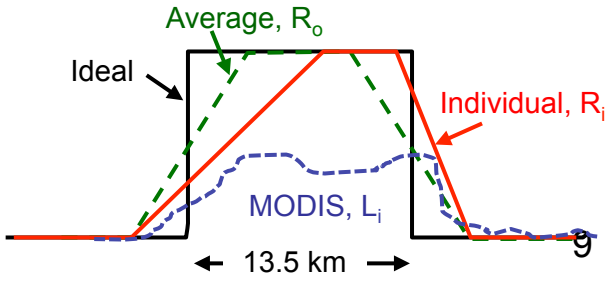
AIRS L1B Uncorrected -
MODIS Averaged to "Ideal" PSF

AIRS L1B Uncorrected -
MODIS Averaged to "Avg" PSF

AIRS L1C (PC Recon+L1B) -
MODIS Averaged to "Avg" PSF

AIRS L1C PC Recon -
MODIS Averaged to "Avg" PSF

AIRS L1B Corrected to "Avg" PSF -
MODIS Averaged to "Avg" PSF



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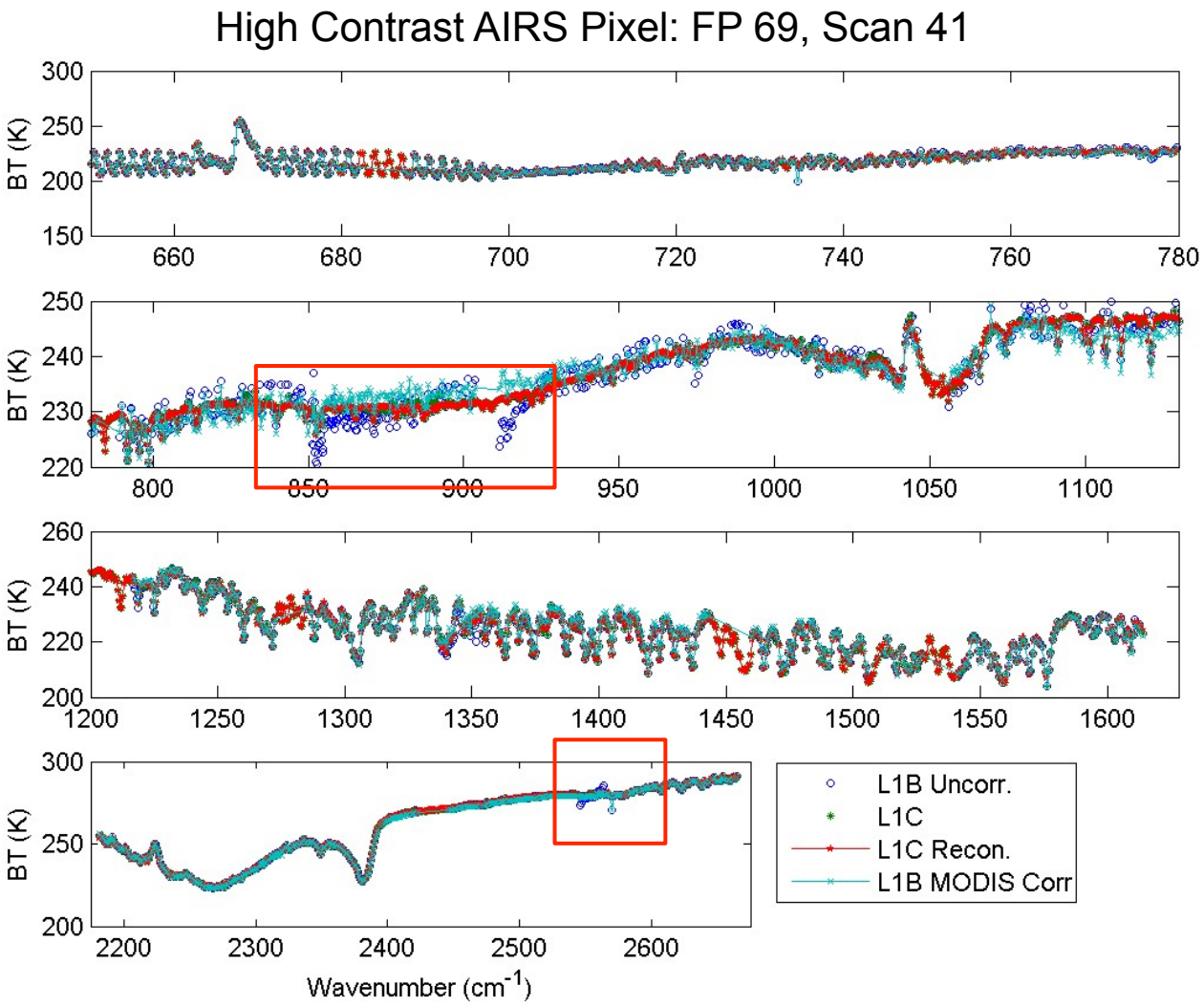
Two Areas of the Spectrum are Most Impacted by Spatial Inhomogeneity Errors



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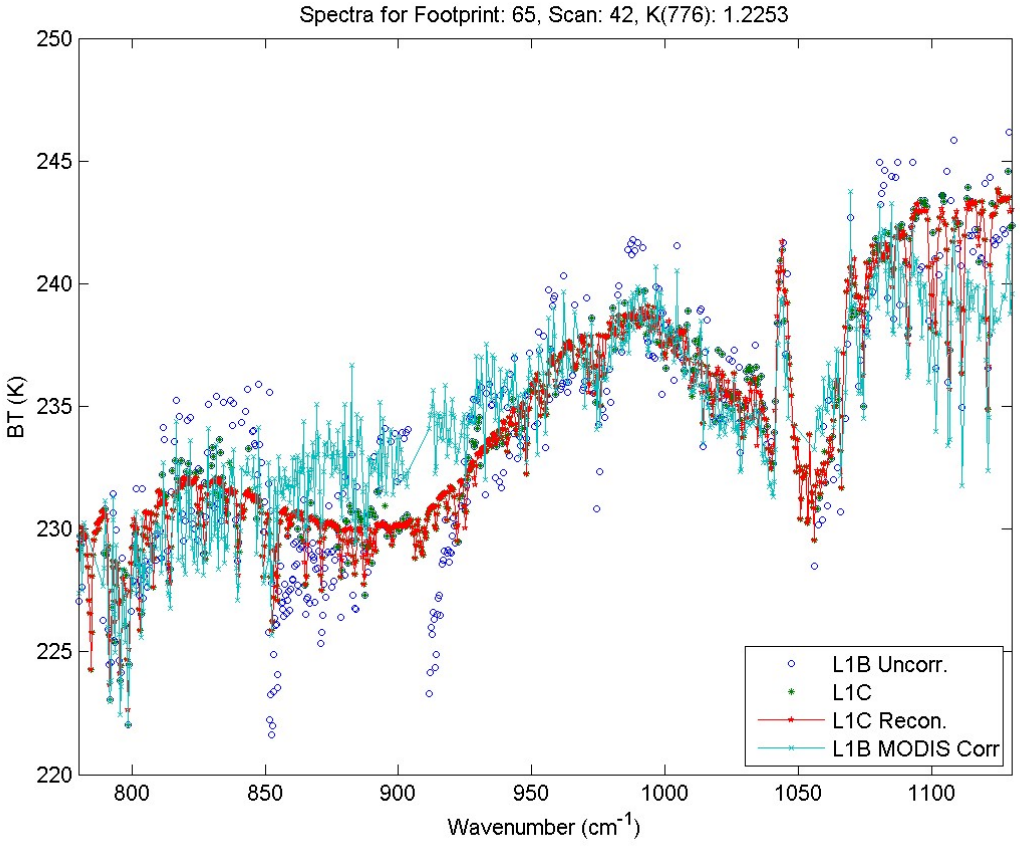
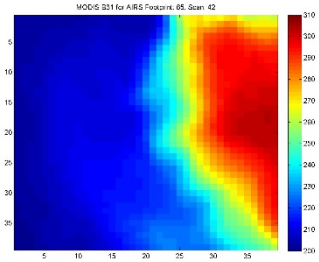
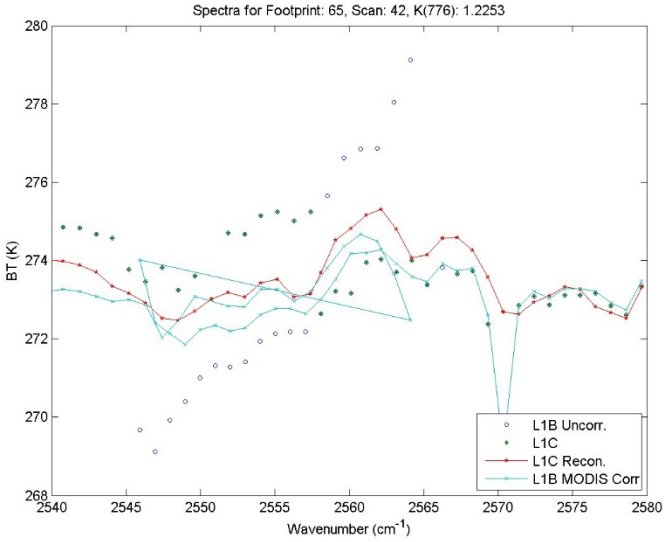
Spectrum Example 1: High Contrast Right







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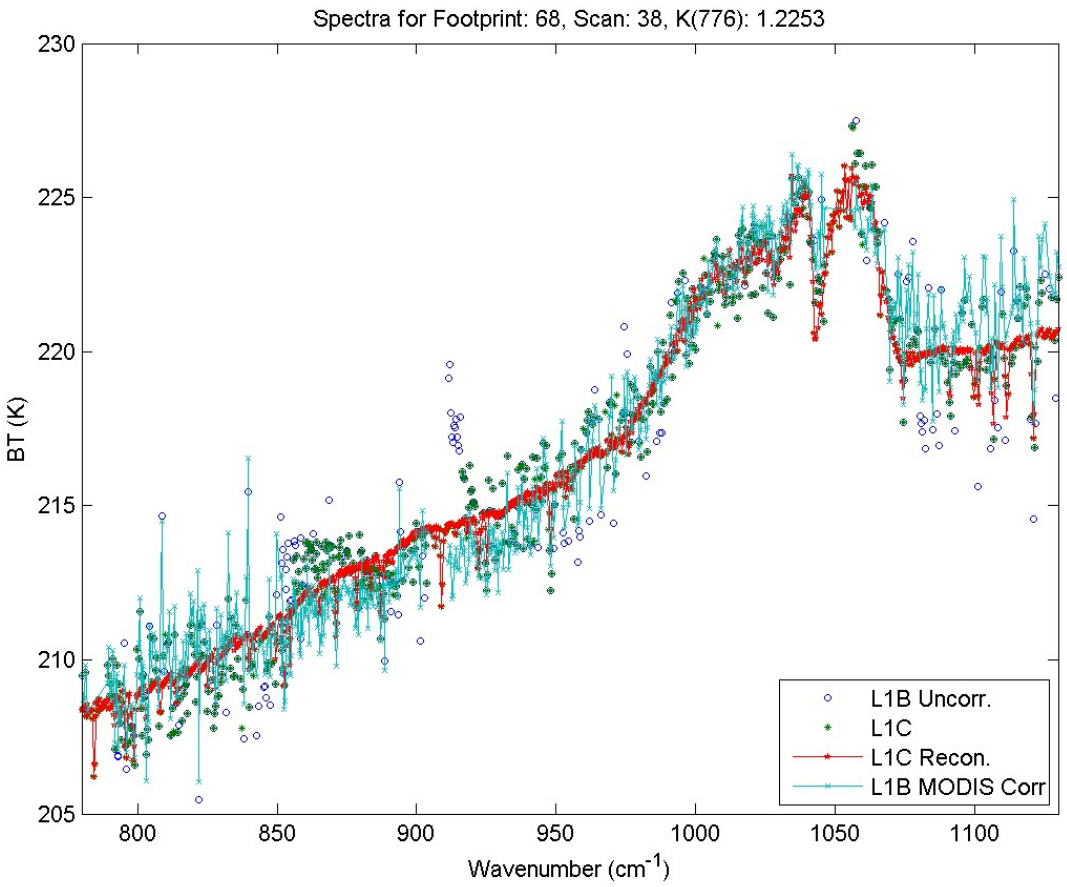
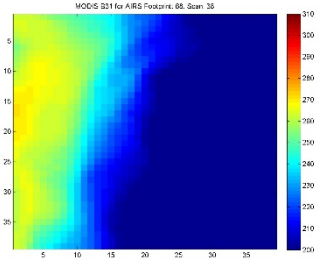
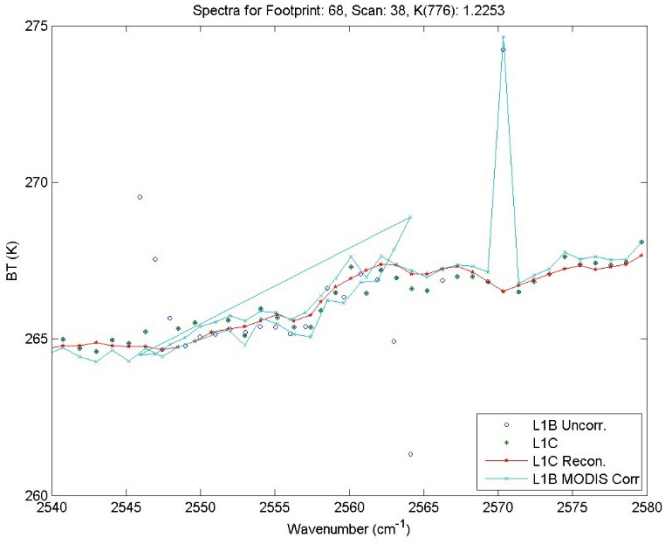
Spectrum Example 2: High Contrast Left







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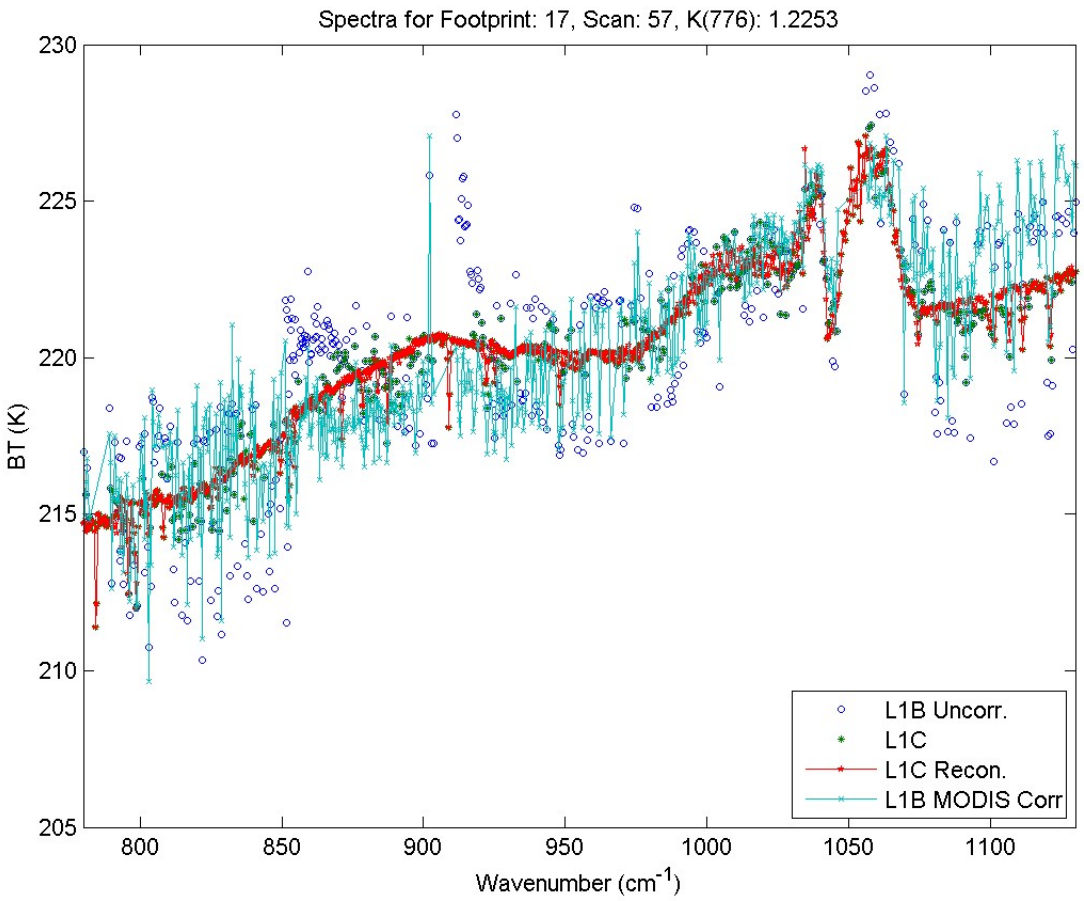
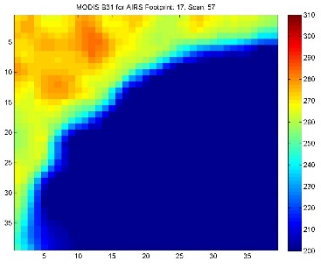
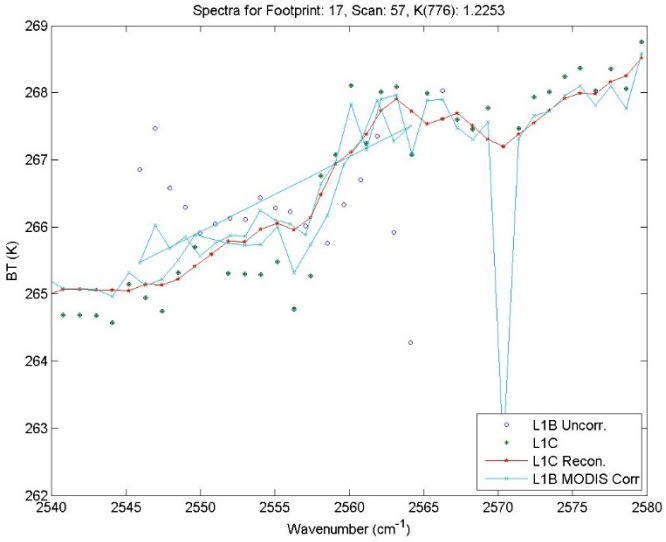
Spectrum Example 3: High Contrast Top







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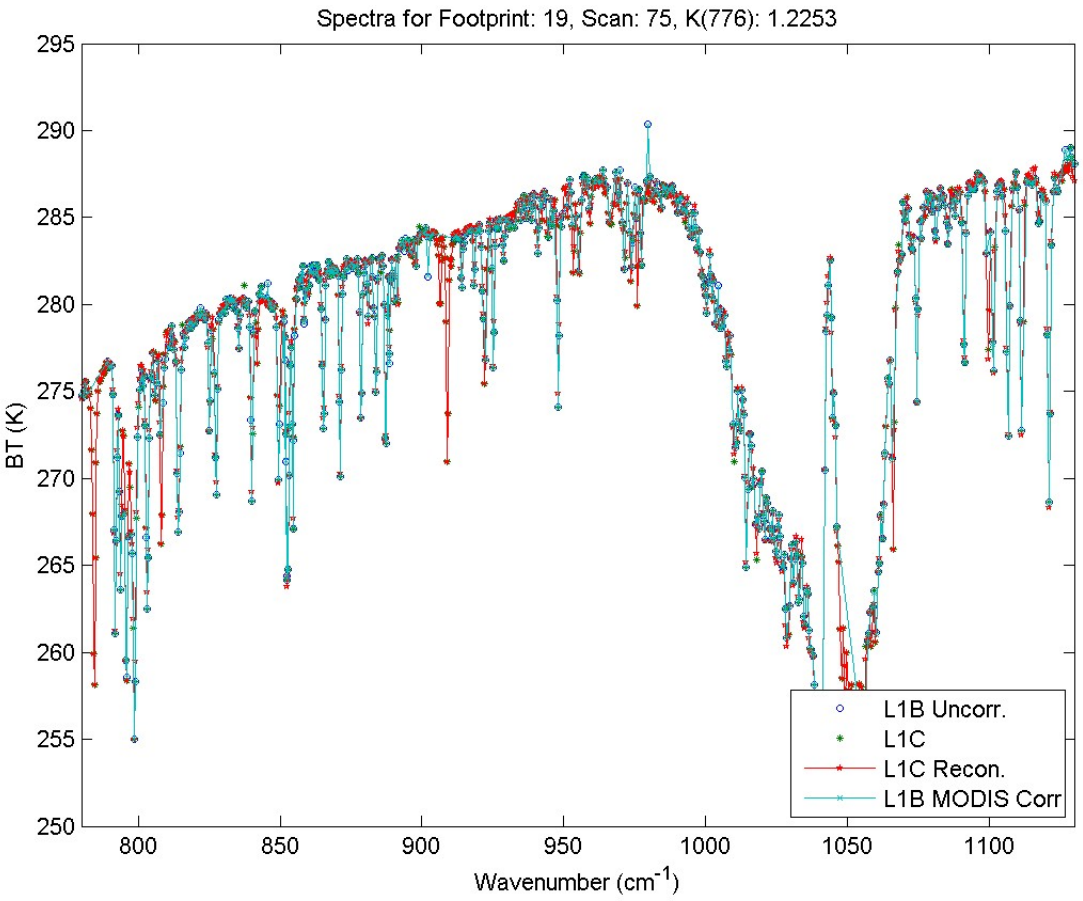
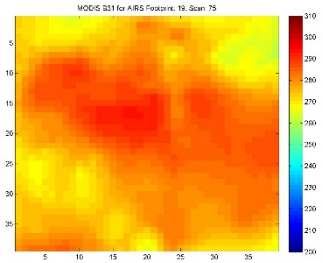
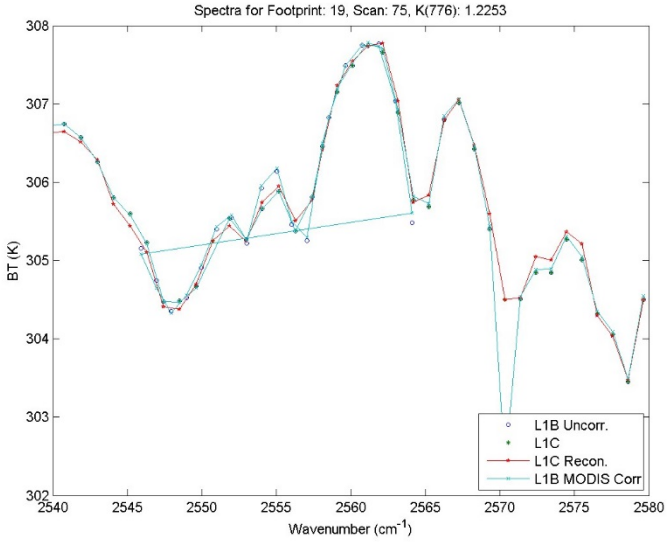
Spectrum Example 4: Low Contrast Hot







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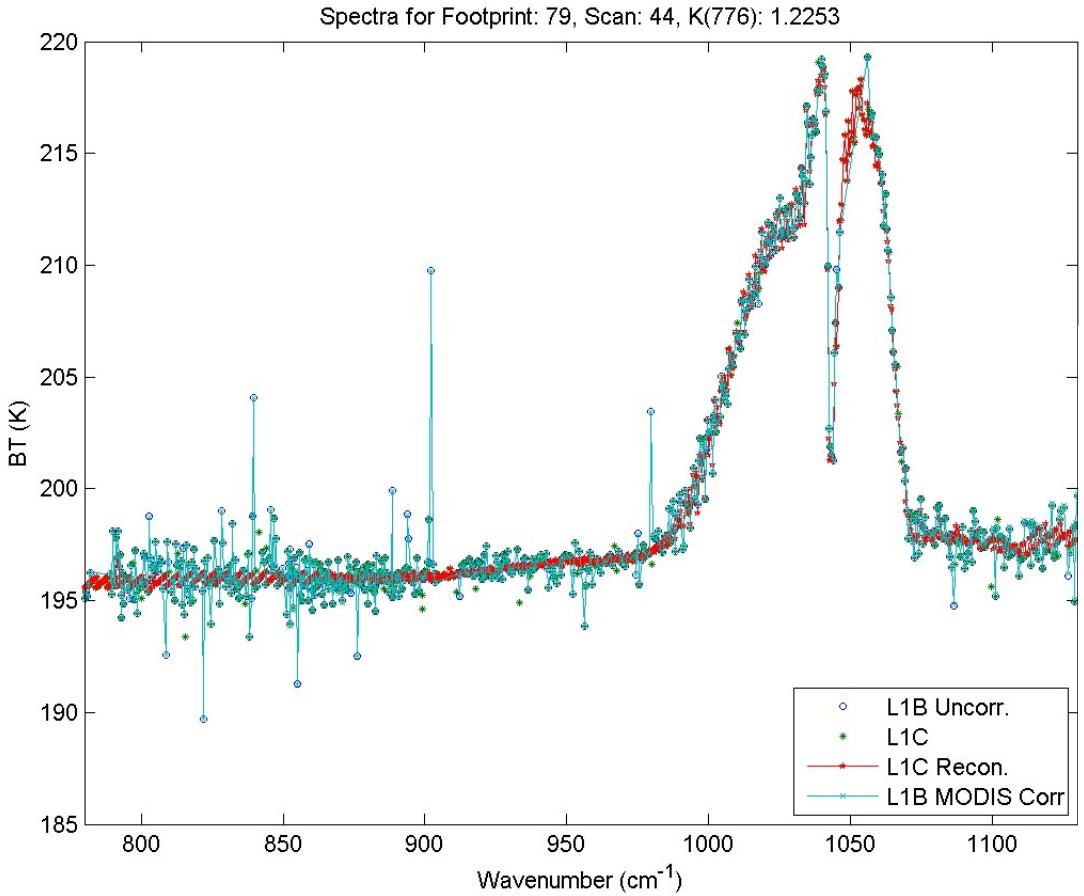
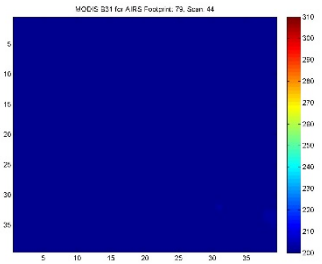
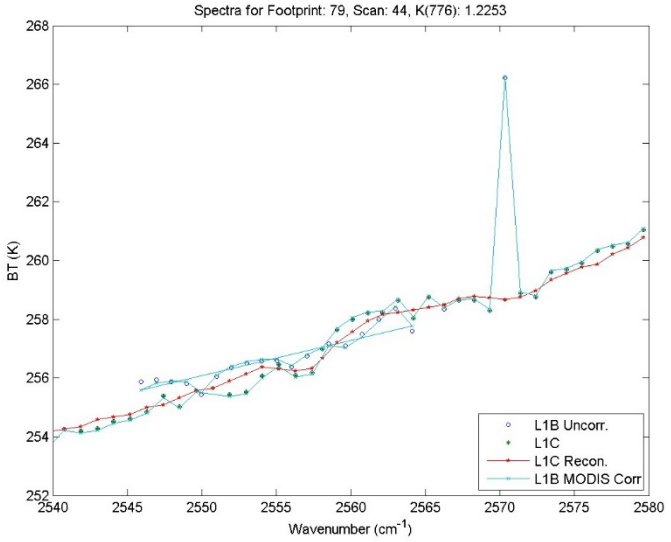
Spectrum Example 5: Low Contrast Cold







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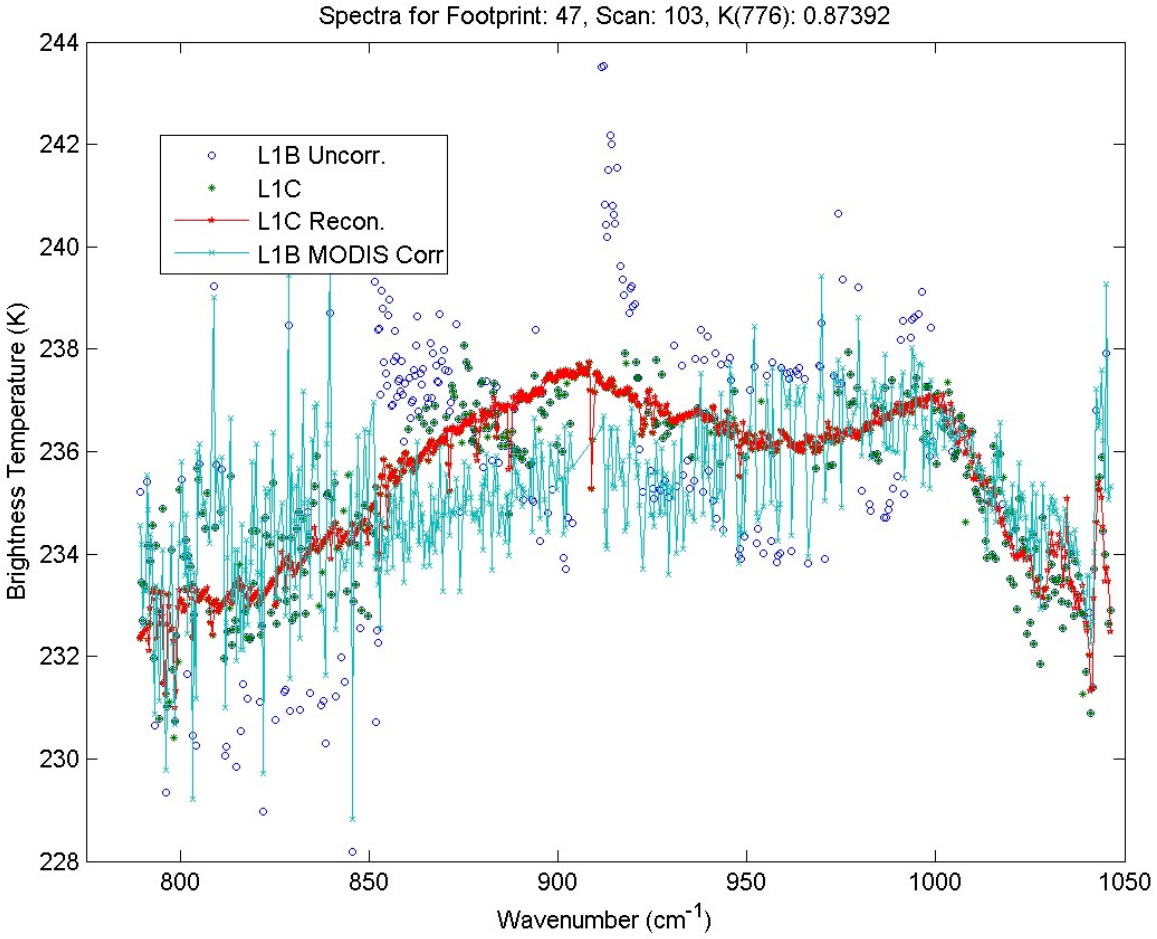
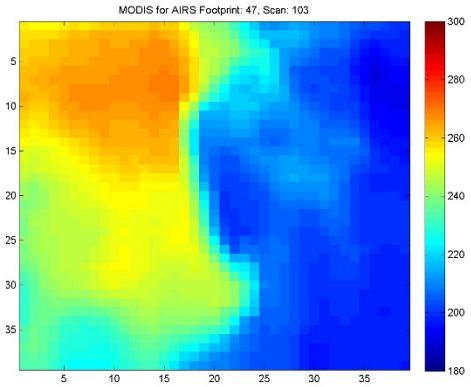
Example 6: Descending Granule





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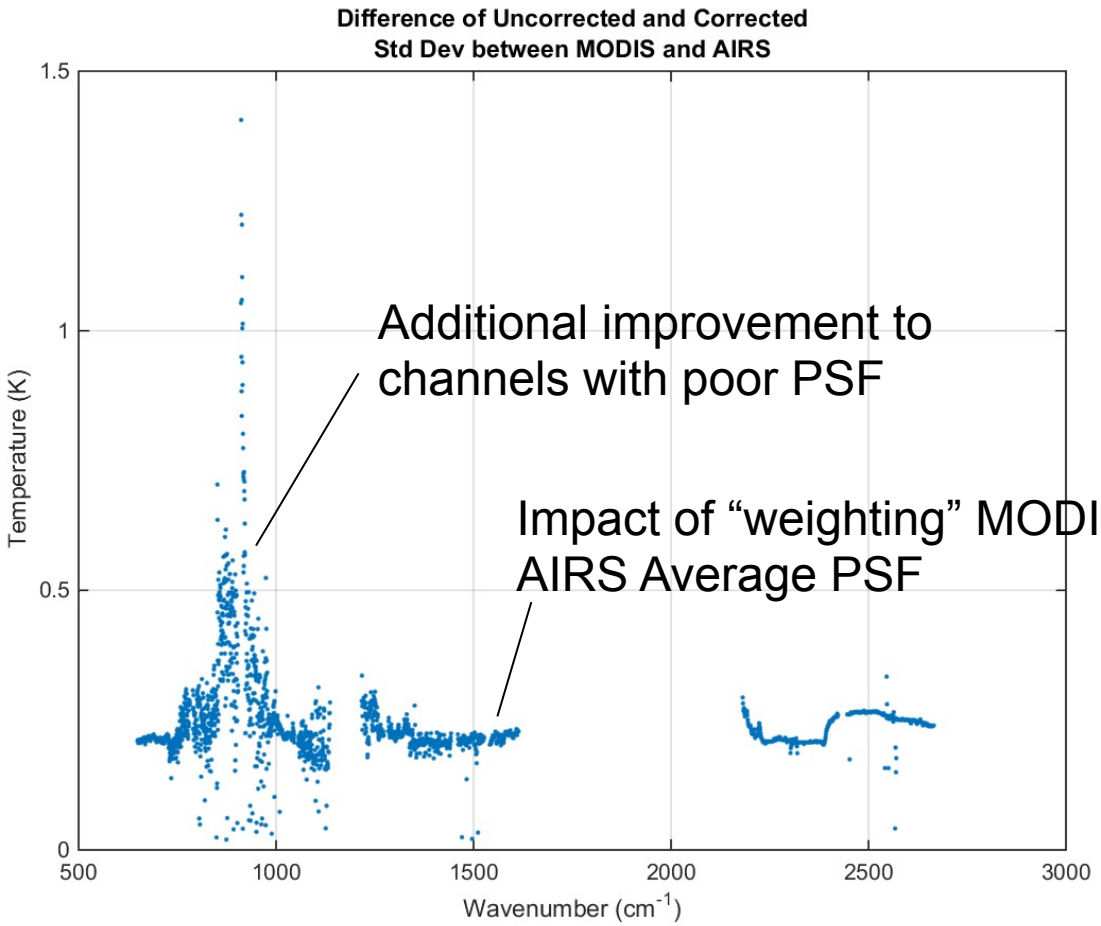
Correction Reduces Std Dev AIRS-MODIS by more than 0.2K



Statistics apply for at All Channels and All Footprints.

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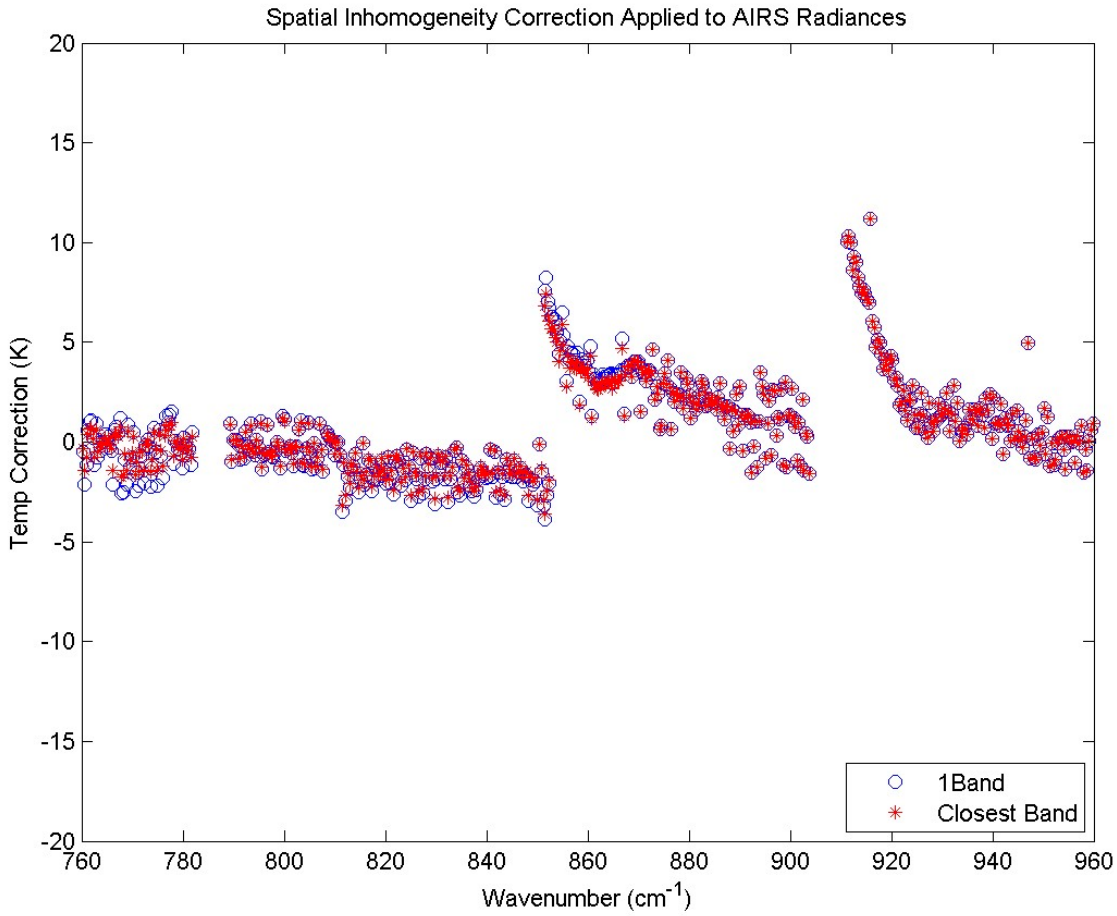
Using closest MODIS band (vs B31) changes correction by < 20%



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No Significant Scan Angle Dependence of Correction

Scan Angle Dependence

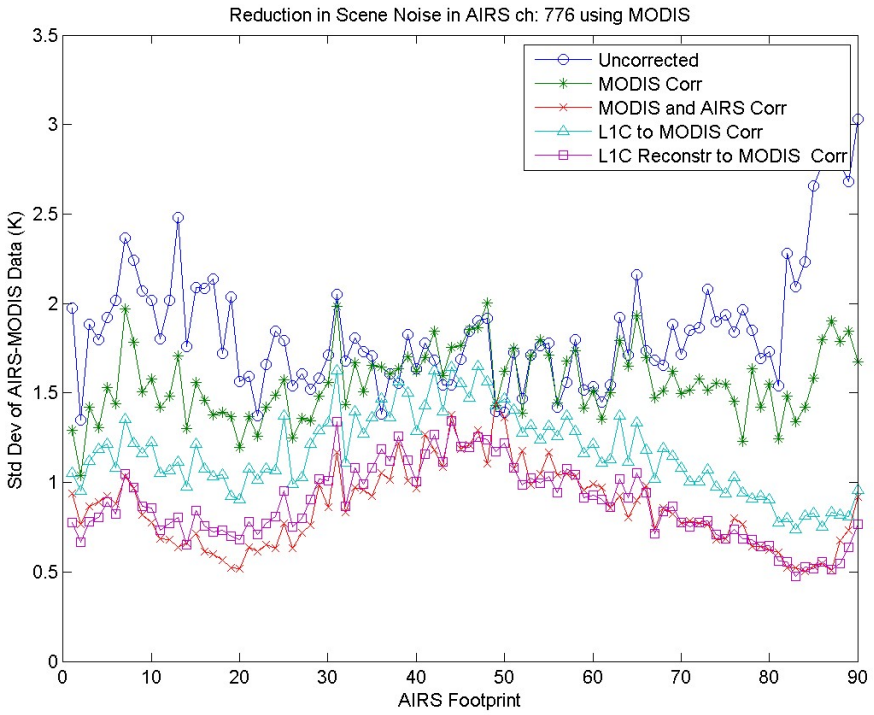
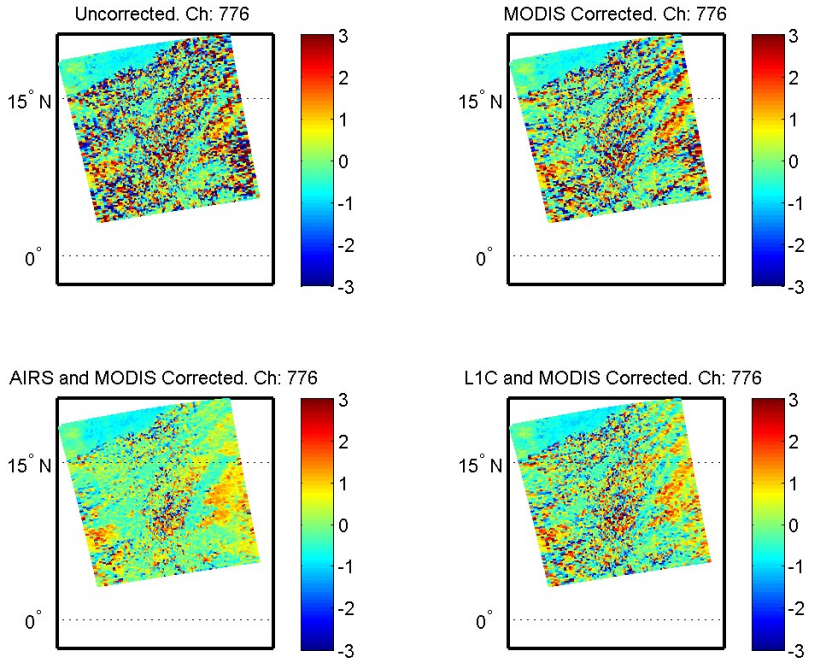


Image of AIRS-MODIS



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Conclusions

- Summary
  - MODIS can be used to reduce effects of scene inhomogeneity on AIRS channels with irregular PSFs
  - Works well. Reduces variability between AIRS and MODIS in nonhomogeneous scenes
  - Algorithm: Robust, not sensitive to biases between MODIS and AIRS
- Future Benefits:
  - Recover channels thought to be useless due to spatial response errors
  - Level 1C. Run MODIS spatial correction prior to PC reconstruction
  - Cloud Clearing. Reduce noise in the cloud clearing process.
  - Improve scene-derived radiometric calibration estimates
  - Improve near surface products over land and cloudy regions
- Remaining Work
  - Improve processing speed
  - Run as a pre-processor to L1C